PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Improvements in or relating to the Checking of Sheet Material for Optically Detectable Irregularities

We, FELDMUHLE PAPIER-UND ZELLSTOFF-WERKE AKTIENGESELLSCHAFT, a Company recognized by German Law, of Burggrafenstrasse 7, (22a), Dusseldorf-Oberkassel, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to

device, such methods providing for a multitude of individual single test devices, each equipped with light source and photocell, distributed across the width of the web. This proposal, too, has failed to provide results of any practical value because the device does not respond to certain kinds

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By a direction given under Section 17 (1) of the Patents Act 1949 this application proceeded in the name of Feldmuhle Aktiengesellschaft, a Body Corporate organised according to the Laws of Germany, of Burggrafenstrasse 7, Dusseldorf, Germany.

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because, in the known apparatus, a large area of paper surface is illuminated at any one time, a small black spot on glossy white paper does not result in a measurable deviation from the standard amount of reflected light.

The problem with which the present invention is concerned is not the measurement of the average reflectivity of a paper surface (which is the quantity determined by the known form of apparatus referred to above) but the detection of variation in the optical properties of sheet material even when the variations only extend over a small area. Thus, for example, the invention is concerned with the detection of small dark spots on an otherwise white surface or of small holes in the material. Previous proposals also include methods for the continuous checking, by means of photocells, of paper webs travelling through the

of checking sheet material for optically detectable irregularities, which comprises feeding the material through a scanning zone, maintaining the material in the scanning zone in a substantially flat and flutter-free condition, scanning the material in the scanning zone with a beam of light arranged to form on the material an illuminated spot having a sharply defined boundary within which the degree of illumination is substantially uniform, which spot moves in a direction transverse to the direction of movement of the material through the scanning zone, detecting variations in the intensity of the light reflected and/or transmitted by the sheet material by means of a photo-electric device and feeding the output of the photo-electric device to a limiter stage arranged to give a fault-indicating signal only when the output of the photo-electric device deviates from a given value

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We, FELDMÜHLE PAPIER-UND ZELLSTOFFWERKE AKTIENGESELLSCHAFT, a Company recognized by German Law, of Burggrafenstrasse 7, (22a), Dusseldorf-Oberkassel, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to the continuous checking of sheet material, for example paper, board and foil, for optically detectable quality deviations.

Apparatus for checking the surface properties of paper is known, which includes photocells and which enables individual paper samples to be assessed, but such apparatus is unsuitable for continuous checking, first because of the long time taken by the test and secondly because of the insufficient resolving power of the apparatus. Because, in the known apparatus, a large area of paper surface is illuminated at any one time, a small black spot on glossy white paper does not result in a measurable deviation from the standard amount of reflected light.

The problem with which the present invention is concerned is not the measurement of the average reflectivity of a paper surface (which is the quantity determined by the known form of apparatus referred to above) but the detection of variation in the optical properties of sheet material even when the variations only extend over a small area. Thus, for example, the invention is concerned with the detection of small dark spots on an otherwise white surface or of small holes in the material. Previous proposals also include methods for the continuous checking, by means of photocells, of paper webs travelling through the device, such methods providing for a multitude of individual single test devices, each equipped with light source and photocell, distributed across the width of the web. This proposal, too, has failed to provide results of any practical value because the device does not respond to certain kinds of fault such as, for example, narrow wedge-like faults which advance with the wedge point foremost into the field of a photocell and thus do not cause any sudden variation of the photocurrent. Finally, checking devices have been proposed in which merely one narrow strip in a moving paper web is examined for faults by means of a photocell, the result of this examination then being applied to the entire width of the web according to the laws of probability. This, however, only gives an indication of the probable means quality of the material.

The present invention provides a method of checking sheet material for optically detectable irregularities, which comprises feeding the material through a scanning zone, maintaining the material in the scanning zone in a substantially flat and flutter-free condition, scanning the material in the scanning zone with a beam of light arranged to form on the material an illuminated spot having a sharply defined boundary within which the degree of illumination is substantially uniform, which spot moves in a direction transverse to the direction of movement of the material through the scanning zone, detecting variations in the intensity of the light reflected and/or transmitted by the sheet material by means of a photo-electric device and feeding the output of the photo-electric device to a limiter stage arranged to give a fault-indicating signal only when the output of the photo-electric device deviates from a given value

by a quantity exceeding a certain magnitude.

The invention also provides apparatus for checking sheet material for optically detectable irregularities, which comprises means for feeding the material through a scanning zone, means for maintaining the material in the scanning zone in a substantially flat and flutter-free condition, means for scanning the material in the scanning zone with a beam of light arranged to form on the sheet material a spot of light having a sharply defined boundary within which the degree of illumination is substantially uniform and to cause the spot to move transversely with respect to the direction of feed of the sheet material through the scanning zone, photo-electric means responsive to the intensity of the light reflected and/or transmitted by the material, and a limiter stage connected to the output of the photo-electric means and arranged to give a fault-indicating signal only when the output of the photo-electric means deviates from a given value by a quality exceeding a certain magnitude.

The output of the photo-electric means may be arranged to trigger fault-indicating signals. If a very small light spot is used, then, for example, even a very small black spot on a white paper surface will result in a marked variation of the instantaneous value of the output current of the photo-electric means, that is to say in a clear indication of the occurrence of a fault in the paper. The dimensions of the scanning light spot may be controlled by means of a diaphragm having a variable aperture. The minimum dimensions of the scanning light spot are determined merely by the requirement that any subsequent scanning strip should touch, or slightly overlap, the preceding scanning strip in order to ensure the complete scanning of the entire paper surface. The size of the light spot is thus related, on the one hand, to the speed with which the material is advanced through the scanning zone and, on the other hand, to the number of scanning movements made in unit time. This relationship can be easily explained by a numerical example. If, for example, the scanning movement is produced by a mirror drum driven at 3000 r.p.m. and the drum is composed of twenty individual mirrors, this drum at 50 revolutions per second, will effect 50×20=1000 scanning movements per second. If the material is advanced through the scanning zone at a speed of 2 metres per second, the centres of two successive scanned regions on the material will be 2 millimetres apart from one another, and the light spot (which is preferably rectangular in shape) in this case must have an extension of at least 2 millimetres in the direction of movement of the material. The extension in the direction transverse to the direction of movement of the material may be as small or smaller than this.

If it is desired further to decrease the size of the light spot in order to increase the response sensitivity of the apparatus, the number of mirror drum revolutions can easily be increased whereby successive scanning regions, at the same rate of feed of the material, will be positioned more closely to one another. If the rate of rotation of the mirror drum is increased, it is also possible, of course, while keeping the other conditions constant, to increase the rate of feed of the material and thereby to increase the efficiency of the whole test device. The speed increase can, for example, be effected by transmission gear inserted between the mirror drum and a motor driving it. In order to avoid vibration of the mirror drum axis, belt drives are recommended for transmission, but specially suitable is the use of a high speed electric motor directly coupled to the mirror drum and supplied, from a network of customary frequency, with current of a frequency suitably stepped up by means of a frequency-changer. In this case the gyro-effect of the high speed assembly constituted by the motor and mirror drum ensures vibration-free running by itself.

Thus, as shown already by the numerical example, the apparatus is capable, on the one hand, of carrying out the complete scanning of a web for fault-detection purposes with sufficiently high operating speed and, on the other hand, with the certainty of detecting very small faults. The material to be examined must be guided flatly and without flutter as it passes through the scanning zone, because departures of the material from the correct position, for example, a slight curvature of the material away from the photo-electric means, might give rise to fault-indicating signals. Of course, if the material has an unevenness which cannot be flattened out by means, for example, of a suction device provided at the scanning zone, then a fault-indicating signal will be given. Thus, not only spots on the surface of the material, but also raised places or creases already in the material give rise to fault-indicating signals. Holes in the material can also be detected. When the photo-electric means is arranged to detect variations in the intensity of the reflected light this may be done by providing, in the scanning zone, a support for the material of which the reflectivity is different from that of the material. Thus, if the material is paper having a bright white surface, a dark-coloured support may be employed.

Advantageously, the limiter stage comprises an amplifier that has a non-linear characteristic. Advantageously, the limiter

stage is adjustable to permit variation of the said magnitude. It then becomes possible to set the apparatus for the particular minimum magnitude of deviation from standard that it is desired shall give rise to a fault-indicating signal. However, if it is desired that very small deviations from standard shall give rise to fault-indicating signals, care must be taken to ensure that the intensity of the incident scanning beam remains accurately constant. This can be done by using, to form the beam, a lamp supplied by a constant-voltage source, for example, a generator driven by a constant-speed motor.

A number of forms of apparatus for checking sheet material for optically detectable irregularities and constructed in accordance with the invention will now be described by way of example in greater detail with reference to the accompanying drawings, in which:—

Figure 1 is a diagrammatic side view, partly in section, of one form of apparatus;

Figure 2 is a section taken along the line II—II in Figure 1, but showing certain modifications of the apparatus;

Figure 3 is a diagram showing a typical output of the photo-electric means and the effect of the limiter stage;

Figure 4 is a perspective view of a form of apparatus similar to those shown in Figures 1 and 2, but having additional devices for forming the scanning light beam;

Figure 5 is a circuit diagram of an electric circuit for causing the output of the photo-electric device to operate devices for sorting sheets of material in accordance with the irregularities on them;

Figure 6 is a diagram showing the layout of an apparatus for examining both surfaces of single sheets of material and sorting the sheets in accordance with any irregularities present; and

Figure 7 is a diagram of a form of apparatus wherein variations in the intensity of the transmitted light are detected.

In Figure 1 of the drawings, there is shown an apparatus for checking the upper surface of a continuous web 10 of sheet material, for example, white paper, for optically detectable faults. The web 10 is fed through a scanning zone by means of two pairs of co-operating endless belts 11 which run over rollers 12 mounted with their axes horizontal. One pair of endless belts 11 is situated in advance of the scanning zone and serves to feed the web 10 to the scanning zone and the other pair of endless belts 11 is situated in rear of the scanning zone and serves to withdraw the web 10 from the scanning zone.

Enclosing the scanning zone is a casing 13, which has apertures in one pair of opposing side walls for the web 10 and endless belts 11 to enter and leave the scanning zone. The casing 13 serves to exclude extraneous light from the scanning zone. Also, pump and filtering means (not shown) are provided for supplying filtered air to the interior of the casing 13 at a superatmospheric pressure. Thus, in conjunction with the pump and filtering means, the casing 13 serves to keep the scanning zone free from dust and dirt.

Within the casing 13, the web 10 is supported on an endless belt 15 running on rollers 14 of which one is driven. The driving means for the driven one of the rollers 14 is so coupled to the driving means for the driven rollers on which the belts 11 run that all the belts 11 and the belt 15 run at the same speed. The belt 15 is air-permeable and dark. It may be, for example, a black perforated web having a narrow mesh. The dark colouring of the belt 15 ensures that, if the scanning spot passes over a hole in the web 10 (which is assumed to be white), the intensity of the reflected light changes substantially. Instead of using an endless belt 15 of dark colouring, it is possible to use an endless belt 15 of good transparency backed by a dark support. The endless belt 15 runs over a suction box 16, which is of known construction and of which the interior is in communication with a vacuum pump (not shown) arranged to maintain the box 16 at a reduced pressure. The top wall of the box 16 is perforated and the suction applied to the sheet material 10 through these perforations and the perforations in the endless belt 15 suffices to maintain the sheet material flat and free from flutter during its passage through the scanning zone, which is a narrow strip 17 extending along the centre line of the suction box 16 in a direction perpendicular to the direction of feed of the web 10.

In the scanning zone 17, the upper surface of the web 10 of sheet material is scanned by a light beam 20 produced by a light source 21 mounted on the outside of the casing 13, the light beam 20 entering the casing 13 through a window. The light source 21 is of great brightness and high luminous density. Thus it may be, for example, a very high pressure mercury vapour lamp or a very high pressure Xenon lamp, the latter having the advantage that the spectral distribution of the radiation emitted by it is substantially uniform throughout the entire visible spectrum so that it can be used for the checking of sheet materials of different colours and for the detection of coloured irregularities.

By means of reflector devices (not shown) arranged behind the lamp 21 and by suitable lenses (not shown) arranged in the path of the light beam 20, the light emanating

from the lamp 21 is focused to form a narrow beam directed on to a mirror drum 22 mounted coaxially on the shaft of a high speed motor 23. The sides of the mirror drum 22 are formed by twenty similar plane mirrors arranged so that the angle between the mirrors of all the pairs of adjacent mirrors are the same. Thus the transverse cross-section of the drum 22 is a regular polygon of twenty sides. The motor 23, and therefore the mirror drum 22, is arranged to run at a speed within the range of from 3000 to 9000 revolutions per minute.

The light beam 20 is reflected by the mirrors of the mirror drum 22 on to the upper surface of the web 10 of sheet material in the scanning zone 17 and each single mirror, because of its rotation, causes the light spot formed on the web 10 in the scanning zone 17 to travel across the web 10 in a direction perpendicular to the direction of movement of the web 10 through the scanning zone 17, from one edge of the web 10 to the other. A part of the light reflected from the upper surface of the web 10 is received by a photo-electric device 24 which is mounted within the casing 13, in a position to which the light beam 20 would proceed if the part of the web 10 in the scanning zone 17 were to be replaced by a plane mirror. The photo-electric device 24 then receives a substantial part of the reflected light despite the fact that the upper surface of the web 10 reflects the light diffusely.

The output from the photo-electric device 24 is fed, via lines 26, to a limiter stage 37, which transmits only signals resulting from departures from the normal intensity of the reflected light received by the photo-electric device 24 that exceed a certain magnitude.

The photo-electric device 24 is preferably a photo-multiplier, that is to say, a device in which electrons emitted as a result of the action of light are utilized first to trigger a secondary and amplified electron emission from a secondary-emission electrode (dynode). In a photomultiplier, a number of such secondary-emission electrodes (dynodes) are arranged in series with the result that light falling on the device produces an electric current of which the magnitude is proportional to the intensity of the light and which can readily be measured. The known photo-multipliers are high-vacuum tubes that fulfil two functions simultaneously. First, they transform light energy into electrical energy, by the electron emission of a photo-cathode, and secondly they amplify this electric energy through electron multiplication, by means of the ~~secondary electron emission from successive~~ electrodes. Each of these electrodes, when one electron impinges on it, emits on the average, for example, four secondary electrons which proceed to the next-following electrode where each of them generates four secondary electrons giving a total of 16 such electrons. Thus, at each stage, the number of electrons is multiplied by the factor four, so that one primary photo-electron in an eleven-stage device causes a total of 4^{11} (which equals approximately 5 million) electrons to be freed and leave the device as its output current. Moreover, the number of photo-electrons produced is, within wide limits, strictly proportional to the intensity of the incident light if it is of constant spectral distribution. The multiplication of any single photo-electron, in the process of repeated secondary electron emission, takes place entirely independently of the multiplication of photo-electrons adjacent in time and space. Therefore, operational conditions being constant, the photo-multiplier output current is proportional to the flux of incident light. Consequently, the transformation of light into primary electrons and the multiplication are independent of frequency provided that the individual processes (all of which occupy less than 10^{-10} seconds) and the variations of electron transit time in the multiplier, together occupy less time than would correspond to one oscillating period of the modulated photo-current, or to the intervals between light pulses. The non-dependence of amplification on frequency ranges from 0 to above 10^7 megacycles per second.

Instead of a photo-multiplier, any other photo-electric device may be used provided that it gives an output current that is both sufficiently large and proportional to the lightflux incident on the device.

Instead of being used for checking a continuous web 10 of sheet material, the apparatus may be used to check individual sheets of material fed through the apparatus at intervals, but means should then be provided for ensuring that the apparatus does not indicate a fault when a gap between successive sheets passes through the scanning zone 17. In Figure 1, the dot-dash lines indicate auxiliary devices provided for this purpose.

The simplest way in which to ensure that gaps between successive individual sheets should not cause fault-indicating signals is to provide means for causing a further light beam to fall on the photo-electric device 24 when such a gap is passing through the scanning zone 17. In the arrangement shown in Figure 1 there are provided two feeler contacts 30, situated in advance of the scanning zone 17 and arranged to make contact with one another ~~to close an electric circuit except when a~~ sheet passes between them. Thus the contacts 30 close each time a gap between

successive sheets passes them. Preferably, there are provided two such pairs of feeler contacts 30 connected in series with one another and situated one close to each edge of the path of the sheets. When the two pairs of feeler contacts 30 close, a current flows through the lines 31 and energises a relay associated with a time delay switch 32. Upon energisation of the relay, and after the elapse of a delay period equal to the time taken for the sheet material to advance from the feeler contacts 30 to the scanning zone 17, the switch 32 closes. The switch 32 opens upon de-energisation of the relay after the elapse of the same delay period. Thus, in operation, the switch 32 is closed only when a gap between successive sheets is passing through the scanning zone 17. The use of two pairs of feeler contacts 30 ensures that tears are indicated as faults, only gaps extending across the whole width of the path of the sheets in a direction perpendicular to the direction of movement of the sheets are not indicated as faults.

Closure of the switch 32 may prevent the production of a fault-indicating signal in either of two ways. In one arrangement, closure of the switch 32 causes energisation of a further light source 33 through a circuit 34. Light from the light source 33 is reflected on to the photo-electric device 24 by a fixed mirror 35 and ensures that the passage of a gap between successive sheets through the scanning zone 17 does not cause a drop in the light flux falling on the photo-electric device 24. Thus the gap does not lead to the production of a fault-indicating signal. In the other arrangement, closure of the switch 32 causes a current to flow in lines 36 to the limiter stage 37, which is thereby prevented from producing a fault-indicating signal.

Another way of preventing the passage of a gap between successive sheets through the scanning zone 17 from leading to the production of a fault-indicating signal is by providing an additional light source 38, which is mounted within the suction box 16 and is arranged to produce a beam directed towards the photo-electric device 24. When the apparatus is in operation for checking individual sheets, the light source 38 is energised continuously and, by causing a beam of light to pass through the perforated top of the suction box 16 and the perforated endless belt 15 and to fall on the photo-electric device 24 when a gap between successive sheets passes through the scanning zone 17, prevents the passage of such an inter-sheet gap through the scanning zone 17 from giving rise to a fault-indicating signal. This arrangement, in the simple form shown in Figure 1, suffers from the disadvantage that it also prevents the passage of holes and tears in sheets from giving rise to the production of a fault-indicating signal, but, as will be described below with reference to Figure 2 and also Figure 6 of the drawings, it is possible to modify the arrangement in such a way as to overcome this disadvantage.

In the modified form of apparatus shown in Figure 2 of the drawings, the endless belt 15 is replaced by a perforated drum 40 mounted so that its axis extends horizontally and is vertically beneath the centre line of the scanning zone 17. The web 10 (or the individual sheets) is fed over the top of the drum 40 by two pairs of co-operating endless belts 11 as shown in Figure 1. The suction box 16 is replaced by a suction mounted within the drum 40. The perforated drum 40 is supported by bearings 42 in the walls of the casing 13 and is driven through a gear wheel 43, which is so coupled to the driving means for the endless belts 11 that the peripheral speed of the drum 40 is equal to the rate of feed of the belts 11. The suction box 41 is fixedly supported on tubular pieces 44, which pass through the hollow journals of the drum 40. One of these tubes serves to place the interior of the suction box in communication with a vacuum pump (not shown) and the other houses electric supply leads 45 for two lamps 38 mounted in the suction box 41.

In Figure 2, the scanning means, apart from the mirror drum 22 and driving motor 23, is omitted. In this form of apparatus, the light beam falls on the mirror drum 22 in the direction of view in Figure 2 and is reflected by the drum 22 on to the web 10 in such manner that the axis of the reflected beam lies in the vertical plane containing the centre line of the scanning zone 17. Two photo-electric devices 24, which are connected in series are provided, arranged so that the centres of their light-receiving areas also lie in the said vertical plane. With this arrangement, the output of the photo-electric devices does not, in the absence of any faults in the web 10, vary significantly during the movement of the scanning spot from one end to the other of the scanning zone 17.

Two plane mirrors 25 or strips of material having a somewhat higher reflectivity than the web 10 to be tested are arranged one at each end of the scanning zone 17 so that, if the length of the scanning zone 17 exceeds the width of the web 10, the light flux falling on the photo-electric devices 24 does not decrease when the scanning spot passes beyond the edges of the web 10. It is preferable that the mirrors or strips 25 should be removable mounted so that they can be replaced by others of a differ-

ent size if it is desired to check web or sheets having a different width.

In order to prevent the passage of an inter-sheet gap through the scanning zone 17 from producing a fault-indicating signal, two lamps 38 are mounted within the suction box 41, one towards each end. These two lamps 38 operate generally in the same way as the single lamp 38 in the form of apparatus shown in Figure 1. The arrangement is such, however, that the production of a fault indicating signal is only prevented if light from both the lamps 38 falls on the photo-electric devices 24 at the same time. Thus, with this arrangement, the lamps 38 do not prevent the passage of a hole through the scanning zone 17 from producing a fault-indicating signal. The two lamps 38 may be replaced by a single long fluorescent tube extending along the length of the suction box 41. Referring to Figure 3 of the drawings, which shows a typical output current from the photo-electric devices 24 in the apparatus shown in Figure 2 of the drawings when the apparatus is being used to check individual sheets of material, the current characteristic shows regularly spaced peaks 50. These peaks 50 result from the increase in the intensity of the reflected light that occurs when the scanning light beam passes beyond the lateral edges of the sheets and falls on one or other of the mirrors 25. Thus the distance a between successive peaks 50 corresponds to the time occupied by a single scanning movement of the beam. If, for example, the mirror drum 22 is driven at a speed of 3000 revolutions per minute (i.e. 50 revolutions per second) and has twenty plane mirrors then the beam performs 1000 scanning movements per second and the distance a corresponds to a time of 1/1000 of a second. When an inter-sheet gap passes through the scanning zone 17 then, because of the effect of the lamps 38, the quantity of light falling on the photo-electric devices 24 again increases and gives rise to the increased output current represented by the portions 51 of the curve. The duration b of this current increase 51 depends upon both the length of the inter-sheet gaps and the rate of feed of the sheet material 10 through the scanning zone 17. For example, with an inter-sheet gap of 2 centimetres and a rate of feed of 2 metres per second, it amounts to 1/100 of a second. The interval c between two such increases 51 depends upon the length of the individual sheets of material 10. For example, if the length of the individual sheets is 1 metre, the interval c is 0.5 seconds.

If one of the scanned sheets shows faults, then all of these faults appear in the current characteristic as more or less pronounced troughs 52. It is possible to separate these fault-indicating signals 52 in a simple manner from all other signals by using an amplifier (for example, a single-stage amplifier) having a non-linear characteristic and applying a grid bias which is such that the output current of the amplifier contains only those signals that are represented by troughs extending below a pre-determined cut-off line d—d, that is to say, the troughs 52.

The diagram in Figure 3 also shows the importance of the size of the scanning spot. In the current characteristic shown, the fault-indicating signals 52 reaches the zero line only when a dark spot on the sheet material 10 under inspection is larger than the scanning light spot, which means that the intensity of the light incident on the photo-electric device 24 momentarily falls substantially to zero. If a dark spot on the paper is smaller than the scanning light spot, however, then the fault-indicating signal 52 does not extend to the zero line but only to a point which corresponds to the brightness decrease in the scanning light spot caused by the fault. If for instance the fault-indicating signal amounts to approximately a third of the distance e in Figure 3 it can be deduced that the fault has an area of approximately a third of that of the light spot. It thus becomes apparent that, in order to detect as small faults as possible, it is preferable to operate with the smallest possible size of light spot, and also with the greatest possible scanning speed.

The height of the cut-off line d—d can be adjusted in a very simple way merely by varying the grid bias by means of a potentiometer. The use of such a potentiometer has the substantial advantage that it makes it possible, even while the apparatus is in operation, to vary the maximum magnitude of fault that will give rise to a fault-indicating signal 52.

In most cases, it is desirable to arrange that the cut-off line d—d shall be relatively close to the signals 53 which are being eliminated in the limiter stage 37 so that, in addition to the signals 52, the smaller signals 54, which are caused by the very smallest faults, also give rise to fault-indicating signals. If this is to be achieved, however, it is necessary that the strength of the signals 53, which can be considered as being the standard signals or the noise level of the system, shall be kept as nearly as possible at a constant height above the zero line. If the lamp 21 were to be connected to the ordinary mains supply, even the customary fluctuations in the network voltage would be sufficient to cause undesirable interference. It is therefore advisable that the current from the lamp

21 should be supplied by special generators, which are known *per se* and of which the output voltage remains accurately constant. The use of such special constant-voltage current sources makes it possible to maintain the cut-off line d—d at a considerable distance from the zero line so that very small faults in the sheet material 10 give rise to fault-indicating signals.

In addition to ensuring that the intensity of the light emitted by the lamp 21 remains accurately constant, it is important for some applications that the light intensity in the scanning beam where it is incident on the material 10 should be uniform over the cross-sectional area of the beam and that the beam should have a sharply defined boundary. If these conditions are not fulfilled, with the result that the distribution of incident light over the area of the spot is uneven, then faults having equal areas each smaller than that of the light spot would produce fault-indicating signals of varying strength, according to the accidental position of the faults within the scanning spot area. It is also advisable to provide means which prevent deviations of the light spot from the pre-determined scanning zone 17 because such deviations would also interfere with the accuracy of the fault-indicating signals.

An optical arrangement that takes into account these and other factors is shown diagrammatically in Figure 4 of the drawings. The lamp 21 is housed in a box 60 mounted within the casing 13, current for the lamp 21 being supplied through leads 61. By means of an optical system 62, the light beam emitted by the lamp 21 is deflected and focused in a first image plane 63. A second optical system 64 focuses the light beam on the mirror drum 22, which is driven by the motor 23. The light beam reflected by the mirror drum 22 produces a spot of light on the sheet material 10, which spot sweeps along the length of the scanning zone 17.

In the optical path between the mirror drum 22 and the scanning zone 17, a rod-shaped lens 65 is interposed to focus the light beam on the upper surface of the sheet material 10 in the scanning zone 17. Similarly, between the scanning zone 17 and the two photo-electric devices 24, a further rod-shaped lens 66 is arranged to gather as much as possible of the light reflected by the sheet material 10 and to focus it into a beam that falls on the lenses of the two photo-electric devices 24. The use of lens 66 is preferable to using additional focusing elements such as parabolic or elliptic mirrors because these tend to collect and focus stray light on the photo-electric devices 24 in addition to collecting and focusing light reflected from the sheet material 10 in the scanning zone 17. If the centres of the light-receiving areas of the photo-electric devices 24 and the axis of the light beam leading from the mirror drum 22 to the scanning zone 17 are situated in the same or approximately the same plane, then the two rod-shaped lenses 65 and 66 may be replaced by a single such lens. In the arrangement shown in Figure 4, the photo-electric devices 24 are placed comparatively far outside the plane in which the incident light beam executes a pendulum-like movement, so that they be situated as close as possible to the scanning line. The intensity of the light received by the photo-electric devices increases with their proximity to the scanning zone 17. It is also possible to arrange more than two photo-electric devices 24 along the length of the scanning zone 17, and the photo-electric devices 24 situated even more closely to the scanning zone 17.

In the path of the light beam from the lamp 21 to the mirror drum 22, in the first image plane 63, there is provided a diaphragm device 68, which is mounted so as to be displaceable in two mutually perpendicular directions by means of adjusting screws 67 and which has an aperture through which the light beam passes. The aperture may be in the form of a hole to produce a circular spot or, preferably, in the form of a slit to form a rectangular spot. Preferably, means are provided to enable the effective aperture of this diaphragm 68 to be varied or adjusted.

In order to enable the apparatus to be used for checking different forms of sheet material 10 or for checking the sheet material 10 for different types of fault, a number of filters 69 are mounted so that one or other of them can be moved into the path of the light beam between the lamp 21 and the first optical system 62. In this way, various regions from the overall spectrum of the light source 21 can be eliminated. The filters 69 can be arranged to be moved into and out of the light beam either by hand or automatically. The photo-electric devices 24 may also be arranged to respond to certain regions of the spectral range of the lamp 21.

As in the form of apparatus shown in Figure 1, the output from the two photo-electric devices 24 (which are connected in series with one another) is fed via lines 26 to a limiter stage 37.

The fault-indicating signals from the limiter stage 37 may be made use of in a number of different ways.

If the apparatus is used for the scanning of webs of great length preliminarily wound to form rolls for further working at a later stage, the signals supplied by the limiter stage 37 can be applied to a recording

device from which a record strip is taken for every roll. During further processes undergone by these rolls it will clearly appear from these record strips which portions of the web show faults so that these faulty portions can either be cut out of the web as it is fed into a subsequent processing device, or the faulty portions can be eliminated upon completion of such a further working process. As an example of the latter procedure, finished prints produced on a rotary printing press are, at the output end of the press, split into sheets before being delivered, and faulty specimens can be removed from the stack. If automatic devices are employed for eliminating faulty portions of the material, the record strip following the limiter stage 37 may be in the form of a perforated card, which can be electrically scanned to trigger means for eliminating faulty portions of the material. The fault-indicating signals can of course also be recorded magnetically on magnetic tapes or any other known signal-storing device which can then, during further working processes, be employed for fault-indication or for the switching of fault-eliminating devices.

When the apparatus is being used to check single sheets directly, the fault-indicating signals can be arranged to actuate switching devices for the elimination of faulty sheets. It is also possible to exploit the fault-indicating signals both for recording and for switching purposes. It may, for example, be useful, during continuous checking of webs of great length in a foil-producing machine (paper-making machine), in addition to obtaining a record strip for each roll manufactured, to arrange that the fault-indicating signals shall trigger audible or visual signals immediately a fault is detected. In this way, the apparatus can be used not only to provide retrospective information as to whether and where faults have occurred during production, but also to provide information that can be used by a machine operator to prevent recurrence of the faults. In such a case it is useful that two consecutive signals should be produced by a single fault-indicating signal, the first of which is given immediately the fault passes through the scanning zone 17 and may, for example, be a ring on a bell and the second of which signals is given at an instant that coincides in time with the passage of the fault through an easily supervisable station further down the path of the web, for example, as the web enters the winding mechanism. In this case the second signal is preferably a visible signal, such as the lighting up of a lamp. The machine operator, called to this place by the bell signal, is warned by the lighting up of the lamp that the fault should now become visibl and he is thus enabled to inspect the type of fault that has occurred and, if it should prove to be necessary, to take steps gainst its recurrence. For example, the fault might be caused during the production process by the occurrence of foam in the strainer section of a paper-making machine, or by similarly obviatable disturbances.

As mentioned above, the signals transmitted by the limiter stage 37 are capable not only of being utilized in recording devices, but also directly for the control of devices by which, for example, faulty products can be separated from faultless products. An example of an electric circuit arrangement suitable for controlling such sorting devices is shown diagrammatically in Figure 5. In this arrangement, single sheets 70 are fed in the direction of the arrow 71 through a scanning zone 17 by conveyor means, which are not shown. Variations in the intensity of the reflected light are detected by photo-electric devices 24 of which the output current is fed to a limiter stage 37.

The short-duration current pulse transmitted by the limiter stage 37 and caused by a fault 72 on one of the sheets 70, is applied to a relay 73. The associated switch 74 is preliminarily closed by a sprung pawl 75, but current is prevented from flowing through the switch 74 at this stage by an interrupter 76, which is mounted on a shaft 77 and is connected in series with the switch 74. The shaft 77 is so coupled to the means for feeding the sheets 70 through the scanning zone 17 that it executes one revolution in the time that elapses between the leading edge of one sheet 70 passing a fixed point and the leading edge of the next succeeding sheet 70 passing the same point. Thus the shaft 77 and the feeding means may have a common drive. The purpose of the interruptor 76 is to delay the actuation of an ejector 78 until the leading edge of a sheet 70 having a fault 72 approaches the ejector 78. When actuated, the ejector 78 deflects every faulty sheet downwardly from the normal path indicated by the arrow 71. The faulty sheets may be deflected, for example, into a waste basket located below and to the rear of the ejector 78.

When the sheet 70 having a fault 72 reaches a position in which the leading edge of the sheet 70 is close to the ejector 78, a conductive metallic portion 79 on the insulating interruptor disc 76 meets an associated wiper contact, thereby closing the circuit through the switch 74 and energising a relay 80, which moves the ejector 78 to a position in which it deflects the faulty sheet downwardly. In the form

of apparatus shown in Figure 5, the front edge of the ejector 78, in order to simplify the circuit, is spaced apart from the centre line of the scanning region 17 by a distance exactly equal to the distance *e* separating the leading edges of two adjacent sheets.

From this it follows that in this circuit arrangement the ejector 78 will be actuated correctly even if the fault 72 is located, not in the position shown, but in close proximity to either the leading or the trailing edge of a sheet. If the distance *e* were to be reduced, sheets having faults near the trailing edge would not be correctly deflected and, if the distance *e* were to be increased additional delay or storage devices would have to be provided.

Shortly after the instant of moving the ejector 78 to its operative position, one inter-sheet gap will therefore be situated above the front edge of the ejector 78 and one above the centre line of the scanning zone 17. The switch 74 must then immediately be opened so that the relay 73 can respond to any fault that there may be in the next following sheet. This is effected by a magnet 81 which, upon energisation, causes a sprung pawl 75 to open the switch 74. Energisation of the magnet 81 is energised at the above-mentioned instant by means of a contact 82 fixed on the shaft 77. In order that the ejector 78 should not be affected by this contact interruption, that is to say, in order that it should stay open until the sheet with the fault 72 has run through it, the armature of the relay 80 actuates not only the ejector 78, but also a switch 83, which short-circuits the switch 74 through a contact 84 on the shaft 77 during the time taken by the passage of one sheet through the ejector 78. When the sheet has passed through, the ejector 78 is returned to its initial position by the action of a spring 85, because then the energisation of the relay 80 is interrupted by the contact 84 unless a fault is detected in the next following sheet, in which case the switch 74 will again have been closed. In the latter case, the ejector remains reversed by the relay 80 because this relay then continues to receive current via the contact 79 and the switch 74.

As will appear from the circuit diagram shown in Figure 5, the switch 74 always responds to the first fault occurring in a sheet, and signals caused by further faults in the same sheet do not alter the switching state. But it may also be desirable to obtain an indication of the number of faults in one sheet. This can be done quite easily by feeding the signals issuing from the limiter stage 37 not only to a switching device in the form of the relay 73, but also to a recording device, which is indicated in Figure 5 at 86. The device in question here is a pulse counter of known construction in which the signals issuing from the limiter stage 37 are counted and their total is transferred to a recording device. This total may then be registered on a recording strip for a certain number of sheets, for example, for every 10 or 100 sheets, and thus supplies the desired information as to the number of faults. The number of faults for single sheets ascertained in a pulse counter can, of course, if the switching devices are altered accordingly, also be utilised to sort out those sheets in which a predetermined number of faults per sheet has been exceeded. The relay 73 in Figure 5 would then be actuated by the pulse counter as soon as the overstepping of a predetermined number of faults has been registered by the counter.

The switching arrangement shown in Figure 5 solves the problem of how to transfer the pulses transmitted by the light-sensitive device 24 at different times in relation to the passage of the leading edges of the sheets past the centre line of the scanning zone 17 to a switching device (the ejector 78) for the course of the sheet, i.e. to the ejector 78, with the changes in the delay time necessary to ensure that the reversal of the ejector 78 takes place at the time when the leading edge of a sheet approaches the ejector 78. This object can, of course, also be achieved with other known delay devices, especially by employing magnetic signal-storage devices which may also be arranged on revolving element (if necessary driven synchronously with the feeding of the sheets). The employment of magnetic storage devices offers the advantage that the stored signals can be erased in good time in a simple and well-known manner so that the storage devices are ready to record new signals immediately after erasing. The arrangement shown in Figure 5 is therefore only one example which can, of course, be replaced by other circuit arrangements with similar effect.

Figure 6 shows diagrammatically a complete plant for checking single paper or board sheets for optically detectable quality deviations, and for sorting these sheets on the basis of faults determined in this way. The sheets to be examined are placed in a stack 90 on a plate 91 which is supported by a lifting table 92 at the feeding end of the test plant. A sheet feeder 93 feeds the sheets singly and at predetermined intervals from the top of the stack 90 to a pair of co-operating endless-belt conveyors 94, which correspond to the conveyor belts 11 shown in Figure 1 and which feed the single sheets to a first scanning region 95. As the means for scanning the upper surfaces of the sheets in the scanning zone 95 is the same as the scanning means shown in Figure 1, only the casing 96 and the conveyor devices, which advance the sheets

over the suction box 97, are shown in Figure 6. On leaving the scanning zone 95, the single sheets are advanced by a pair of co-operating endless-belt conveyors 98 into another casing 99 in which the underside of the sheets is scanned from below in a scanning zone 100. Thus, in this plant, both surfaces of the sheets are checked. Additional endless-belt conveyors 101 then advance the sheets leaving the casing 99 towards three delivery boxes 102, 103 and 104 in which the checked sheets are stacked on lowerable plates which are provided with the usual shaking devices 105 to obtain flush lateral surfaces for the sheet stacks. Distribution of the scanned sheets to the individual delivery boxes is controlled by means of two ejectors 106 and 107, which operate in the same way as the ejector 78 shown in Figure 5.

It is advisable to provide the boxes 102, 103 and 104, or one or more of them, with a sheet counting mechanism 108 of known construction and also, if desired, with known devices for the injection of ream-indicating sheets, these devices being controlled by the sheet counting mechanism.

An advantage of passing the sheets in succession through two scanning zones 95 and 100, it is possible to prevent the inter-sheet gaps from giving rise to fault-indicating signals in a simple manner without at the same time preventing holes from being registered as faults. One lamp is placed in the suction box 97 beneath the scanning zone 95 and another is placed in the suction box above the scanning zone 100, and the two lamps are spaced apart from another in a direction transverse to the direction of feed of the sheets. Thus one lamp is situated towards one line of lateral edges of the sheets and the other line is situated towards the other line of lateral edges of the sheets. Each lamp will prevent inter-sheet gaps from giving rise to fault-indicating signals and may also prevent holes situated in the lateral half of the sheet above the lamp from being registered as a fault, but a hole will then give rise to a fault-indicating signal when it passes through the other scanning zone 95 or 100.

The apparatus shown in Figure 6 is useful for a number of applications. If it were desired only to sort the sheets into perfect sheets and waste sheets, two delivery boxes would be sufficient, but the apparatus can be arranged to sort the sheets in more complicated ways.

The plant can be used, for example, to sort sheets all of which have been shown, by means of a preliminary sorting operation, to contain faults. Thus, the faulty sheets may be so sorted that any sheet having a fault only in its leading half is fed into the box 104, any sheet having a fault only in its trailing half is ejected into the box 103 by an ejector 107, and any sheet having faults in both its leading and trailing halves is ejected into the box 102 by an ejector 106. The stacks of sheets in the boxes 103 and 104 can then be cut in half to give a stack of perfect half-sheets and a stack of faulty half-sheets. As the perfect half-sheets are perfectly usable, this sorting results in a considerable reduction in waste. The circuit arrangement for actuating the two ejectors 106 and 107 has, of course, to be modified as compared with the circuit arrangement shown in Figure 5. The signals emitted by the light-sensitive devices 24 can be fed to a so-called gate circuit, which is known from other applications and which separates from one another the signals relating to the leading and trailing halves of the sheets. If no fault is detected in the leading half of a sheet, neither of the ejectors 106 and 107 is actuated, but if a fault is detected in the leading half of a sheet, then the resulting fault-indicating signal cause the actuation of the ejector 107 after a suitable delay. If no fault is detected during the scanning of the trailing half of a sheet, again neither of the ejectors 106 and 107 is actuated, but if a fault is detected in the trailing half of a sheet the resulting fault-indicating signal is transmitted to a relay, which actuates the ejector 106. This relay must, of course, be connected with the switching device for the ejector 107 by means of a blocking circuit in such a way that the ejector 106 is only actuated if an actuating pulse was also transmitted to the ejector 107 from the leading half of the sheet. If, on the other hand, the leading half of a sheet is free from faults, the ejector 106 is not reversed even if a fault is detected in the trailing half of the sheet. In this way the desired distribution of single sheets into the three delivery boxes 102, 103 and 104 is achieved.

The example just described shows that the method according to the invention can be employed to solve completely different tasks if the circuit arrangements are adapted to a given purpose.

The object of separating a stack of sheets in each of which a fault has already been detected into entirely useless sheets and such sheets in which at least one sheet half can still be used can, of course, also be solved by providing for the scanning of a sheet surface two separate devices each of which only scans a portion of each sheet. This portion need not necessarily be the leading or trailing half of the sheet, but may, if so desired, be the right or left lateral half of the sheet. In apparatus in which single sheets are intended to be checked for faults on each of their surfaces, the apparatus shown in Figure 6 has to be further modified in such a way that the two devices, for scanning from above and from below respectively, are connected in series; in this case, respective

delay devices must be included in the leads to the switching devices for actuating the ejectors 106 and 107, which delay devices bridge the interval in time between the instant at which a sheet enters one of the scanning zones 95 and 100 and the instant at which it reaches the associated ejectors.

The apparatus shown in Figure 6 can also be modified for use in sorting sheets that have not previously been sorted into the delivery boxes 102, 103 and 104 in such a way that sheets having no faults go into the delivery box 104 those sheets which have only small faults, that is to say, "second choice" sheets still marketable for purposes not requiring the highest quality standards, go into the delivery box 103, and those sheets which have more pronounced faults and are therefore useless go into the delivery box 102. This can be achieved, for example, by providing a pair of scanning devices for scanning the upper surfaces of the sheets as well as a pair of scanning devices for scanning the lower surfaces of the sheets, and by arranging that the cut-off line *d—d* shown in Figure 3 is set at one level in the limiter stages associated with one scanning device of each pair and at a different level in the limiter stages associated with the other scanning devices of each pair. Sheets which do not give rise to a fault-indicating signal in any of the scanning devices, proceed without hindrance into the delivery box 104 because they are perfect and will not cause the actuation of the ejectors Signals transmitted by the scanning device set for small faults cause the actuation of the ejector 107 so that any sheet having only such a fault enters the box 103. If in the case of these sheets signals are transmitted also by the scanning device set only for coarse faults, then the ejector 106 is also actuated so that any sheet having a coarse fault enters the box 102.

The apparatus shown in Figure 6 can be used for separating from a stack of faulty sheets those sheets that are free from faults on one surface and have faults only on the other surface. Such sheets can be perfectly well employed for the purpose of one-sided printing (posters). The apparatus shown in Figure 6 can be modified by providing four delivery boxes into which sheets that have not previously been sorted are sorted into sheets having faults on neither side, sheets having faults on the upper side only, sheets having faults on the lower side only, and sheets having faults on both sides.

Apparatus constructed in accordance with the invention can be used to sort sheets in accordance with the colouring of their faults. For this purpose, colour filters, which have been referred to in connection with Figure 4 of the drawings, are used and there are provided two scanning devices located one in rear of the other, one of which operates with light covering the whole spectral range while the other uses, for example, light screened by a yellow filter. The device provided with the yellow filter will respond to all faults, that is to say to black faults as well as coloured (especially blue) faults, whereas the device operating with white light does not register blue faults because of the spectral sensitivity of conventional photo-multipliers. Thus the apparatus shown in Figure 6 can be used with the modification described for use in sorting sheets in accordance with the magnitude of faults) for sorting the sheets under test into three groups: sheets without faults, sheets with blue spots, and sheets with other types of fault.

As well as being used for the detection of faults that can be optically recognised by episcopic means, the invention can equally be applied for checking by transmitted light. One form of apparatus for checking by transmitted light is shown diagrammatically in Figure 7. In this form of apparatus as in the case of the apparatus shown in Figure 1, a web 10 is conducted through a scanning zone 17 by means of endless-belt conveyors 11. But the scanning zone 17 here is not located over a suction box as in the apparatus shown in Figure 1, but between two suction boxes 110 and 111 over which two air-permeable conveyor belts 112 and 113 are laid. The belt 112 is driven at a speed corresponding to that of the conveyor devices 11 whereas the belt 113 is driven at a somewhat faster speed. Above the two suction boxes 110 and 111, the completely flat position necessary for the scanning operation is imparted to the web 10. The fact that the speed of the belt 113 is somewhat higher than that of the belt 11-2 tensions the web 10 within the scanning zone 17 and so causes it to remain flat in the gap between the two suction boxes 110 and 111. The temporary stretching of the web 10 possibly causes thereby many manifest itself in the occurrence of a small sag 114 to the rear of the belt 113 where the web 10 loses its tension and is again advanced at normal speed, by the following endless-belt conveyors 11. In this way, the web 10 is led through the scanning zone 17, without being accompanied by any carrier bands whatsoever. In the scanning zone 17, the web 10 is scanned by a scanning light beam 115 reflected by a mirror drum, in a manner already described, to the scanning zone 17 in which it is able to pass through the web 10 and, so far as it is not absorbed in this web, to be received by a light sensitive device 24, and to be transformed into electric energy which is then translatable in the manner already described, into signals or fault indications. Thus, not only paper webs, but also translucent or transparent foils can be checked by applying the method of the invention and the resulting signals can be

used to record such faults or to actuate switching devices for the elimination of faulty foils. If a transparent web is to be checked by means of a light-sensitive system to which the transmitted part of the scanning beam is applied, and this web has not sufficient stability to be conducted flatly across the scanning zone 17, in the manner shown in Figure 7, then the web 10 can be supported during its passage between the belts 112 and 113 by means of a transparent plate, for example, a plane glass plate, the excess speed of the belt 113 over that of the belt 112 and the degree of vacuum in the box 111 being decreased appropriately to allow for the low web stability.

Thus the application of the invention is not confined to paper products or similar foils, but includes all web or sheet-like products of any derivation in which quality deviations can be determined by the observation of light reflected from or transmitted by the material.

WHAT WE CLAIM IS:—

1. A method of checking sheet material for optically detectable irregularities, which comprises feeding the material through a scanning zone, maintaining the material in the scanning zone in a substantially flat and flutter-free condition, scanning the material in the scanning zone with a beam of light arranged to form on the material an illuminated spot having a sharply defined boundary within which the degree of illumination is substantially uniform, which spot moves in a direction transverse to the direction of movement of the material through the scanning zone, detecting variations in the intensity of the light reflected and/or transmitted by the sheet material by means of a photo-electric device and feeding the output of the photo-electric device to a limiter stage arranged to give a fault-indicating signal only when the output of the photo-electric device deviates from a given value by a quantity exceeding a certain magnitude.

2. A method as claimed in Claim 1, wherein the limiter stage comprises an amplifier having a non-linear characteristic and there is applied to the amplifier such a grid bias that the output current of the amplifier contains a fault-indicating signal only when the output of the photo-electric device deviates from the said given value by a quantity exceeding the said certain magnitude.

3. A method as claimed in either Claim 1 or Claim 2, wherein, in the scanning zone, the sheet material is backed, on the side of the sheet material remote from the scanning light beam, by a surface of which the reflectivity to the beam is substantially different from the reflectivity of the surface of the sheet material scanned by the beam, and the photo-electric device is arranged to detect variations in the intensity of the light reflected by the sheet material.

4. Apparatus for checking sheet material for optically detectable irregularities, which comprises means for feeding the material through a scanning zone, means for maintaining the material in the scanning zone in a substantially flat and flutter free condition, means for scanning the material in the scanning zone with a beam of light arranged to form on the sheet material a spot of light having a sharply defined boundary within which the degree of illumination is substantially uniform and to cause the spot to move transversely with respect to the direction of feed of the sheet material through the scanning zone, photo-electric means responsive to the intensity of the light reflected and/or transmitted by the material, and a limiter stage connected to the output of the photo-electric means and arranged to give a fault-indicating signal only when the output of tha photo-electric means deviates from a given value by a quantity exceeding a certain magnitude.

5. Apparatus as claimed in Claim 3, wherein the limiter stage is adjustable to permit variation of the said magnitude.

6. Apparatus as claimed in either Claim 4 or Claim 5, wherein the limiter stage comprises an amplifier having a non-linear characteristic.

7. Apparatus as claimed in any one of Claims 4 to 6, wherein there is provided a casing arranged to enclose and exclude extraneous light from the scanning zone, and pump and filtering means arranged to supply filtered air at a superatmospheric pressure to the interior of the casing.

8. Apparatus as claimed in any one of Claims 4 to 7, wherein the scanning means comprises a fixed light source, a rotatably mounted mirror and driving means for rotating the mirror, the light source being arranged to produce a light beam which is reflected by the mirror on to the sheet material in the scanning zone and rotation of the mirror causing the scanning movement of the beam.

9. Apparatus as claimed in Claim 8, wherein the scanning means includes a plurality of such mirrors arranged to form the sides of a drum of which the transverse cross-section is a regular polygon and which is mounted for rotation about its axis.

10. Apparatus as claimed in Claim 9, wherein the driving means for the mirror is an electric motor and the mirror drum is rigidly connected to the shaft of the motor.

11. Apparatus as claimed in any one of Claims 8 to 10, wherein the scanning means includes removable light-filtering means situated in the path of the light beam from the light source to the mirror.

12. Apparatus as claimed in any one of Claims 8 to 11, wherein the scanning means includes a diaphragm stop situated in the path of the light beam from the light source to the mirror, the stop being situated in a region of maximum intensity of the light

beam, the effective aperture of the stop being smaller than the cross-sectional area of the light beam at that point and the diaphragm being movable in two directions perpendicular to one another and to the axis of the light beam at that point.

13. Apparatus as claimed in any one of Claims 4 to 11, wherein the scanning means includes a cylindrical lens situated in the path of the light beam from the mirror to the scanning zone so as to focus the light beam on the sheet material.

14. Apparatus as claimed in any one of Claims 4 to 13, wherein the photo-electric means is arranged to be responsive to the light reflected by the material in the scanning zone.

15. Apparatus as claimed in Claim 14, wherein the photo-electric means is arranged to receive light over a region through which the scanning light beam would be reflected if the sheet material in the scanning zone were to be replaced by a plane mirror.

16. Apparatus as claimed in Claim 14 or Claim 15, wherein there is provided a cylindrical lens arranged between the scanning zone and the light-sensitive means so as to collect light reflected from the sheet material in the scanning zone and to direct this light on to the photo-electric means.

17. Apparatus as claimed in Claim 14, wherein the scanning means is so arranged that the axis of the scanning beam lies in a vertical plane that is perpendicular to the direction of feed of the sheet material and extends along the centre of the scanning zone, and the photo-electric means comprises two photo-electric devices arranged to receive light reflected in the said plane from the sheet material and situated one towards each end of the scanning zone.

18. Apparatus as claimed in Claim 17, wherein there is provided a cylindrical lens arranged both to focus the light beam on the sheet material and to collect light reflected from the sheet material in the scanning zone and to direct this light on to the photo-electric devices.

19. Apparatus as claimed in any one of Claims 14 to 18, wherein there are provided, at each end of the scanning zone, members having a high reflectivity arranged to reflect the scanning beam if, during its scanning movement, it passes beyond the lateral edges of the sheet material.

20. Apparatus as claimed in any one of Claims 14 to 19, wherein the means for maintaining the material in the scanning zone in a substantially flat and flutter-free condition is suction means.

21. Apparatus as claimed in any one of Claims 14 to 20, wherein there is provided means for preventing the passage of an inter-sheet gap through the scanning zone from giving rise to a fault-indicating signal.

22. Apparatus as claimed in Claim 21, wherein the said preventing means comprises means for detecting the passage of an inter-sheet gap and a light source arranged to be energised in response to th operation of the detecting means in such manner as to cause light to fall on the photo-electric means throughout the passage of the inter-sheet gap through the scanning zone.

23. Apparatus as claimed in Claim 22, wherein the detecting means comprises two feeler means situated one towards one lateral edge and the other towards the other lateral edge of the path of the sheets to the scanning zone, and on a line substantially perpendicular to the direction of feed of the material, the arrangement being such that the said preventing means is rendered operative only when both feelers detect the passage of a gap simultaneously.

24. Apparatus as claimed in Claim 21, wherein the said preventing means comprises a light source situated on the side of the scanning zone remote from the photo-electric means and arranged to cause light to pass through an inter-sheet gap in the scanning zone and to fall on the photo-electric means.

25. Apparatus as claimed in Claim 24, wherein the arrangement is such that a fault-indicating signal is given unless light from the said light source can pass through the scanning zone along the whole width of the sheet material.

26. Apparatus as claimed in any one of Claims 4 to 13, wherein the photo-electric means is arranged to be responsive to the light transmitted by the material in the scanning zone.

27. Apparatus as claimed in Claim 26, wherein the feeding means comprises a suction box situated in advance of the scanning zone, an air-permeable endless belt passing over the suction box, a co-operating endless belt, a second suction box situated in rear of the scanning zone, a second air-permeable endless belt passing over the second suction box, a second co-operating endless belt and driving means arranged to drive the first air-permeable endless belt and the two co-operating endless belts at the same speed and to drive the second air-permeable endless belt at a higher speed.

28. Apparatus as claimed in any one of Claims 4 to 27, wherein the photo-electric means comprises a photo-multiplier.

29. Apparatus as claimed in any one of Claims 4 to 28, wherein there is provided warning means arranged to give a visible or audible warning signal in response to a fault-indicating signal.

30. Apparatus as claimed in Claim 29, wherein the warning means is arranged to give an audible warning signal when a fault-indicating signal is given and to give a visible warning signal at an inspection position to the rear of the scanning zone after a delay period equal

to the time taken by the sheet material to pass from the scanning zone to the inspection position.

31. Apparatus as claimed in any one of Claims 4 to 30, wherein there is provided recording means for recording faults indicated by fault-indicating signals.

32. Apparatus as claimed in Claim 31, wherein the recording means is coupled to the feeding means and is arranged to record the positions of the faults along the length of the material.

33. Apparatus as claimed in any one of Claims 21 to 25, wherein there is provided separating means responsive to fault-indicating signals and arranged to separate individual sheets having faults from the remaining sheets.

34. Apparatus as claimed in Claim 33, wherein the separating means comprises a deflector and means for feeding the sheets past the deflector after they have passed through the scanning zone, the deflector being movable between two positions, in one of which the sheets are caused to follow one path and in the other of which the sheets are caused to follow a separate path, and means connected to the limiter stage for moving the deflector from one of the said positions to the other.

35. Apparatus as claimed in Claim 34, wherein the deflector is mounted for pivotal movement between an inoperative position, in which it is clear of the path of the sheets, and an operative position, in which it extends across the path of the sheets and deflects them out of that path, and the means for moving the deflector between its operative and inoperative positions is connected to the output side of the limiter stage by circuit means which is such that, upon a fault in a sheet giving rise to a fault-indicating signal, the deflector is moved to its operative position as the leading edge of the sheet approaches the deflector.

36. Apparatus as claimed in Claim 35, wherein the said circuit means comprises first switch means connected in series with the means for operating the deflector and arranged to close in response to a fault-indicating signal, second switch means arranged, when closed, to cause the energisation of a magnet to open the first switch means, third switch means arranged to close and thereby short-circuit the first switch means when the said operating means is energised, fourth switch means connected in series with the first switch means and so coupled to the feeding means that it closes at intervals equal to the time taken for the leading edge of a sheet to pass from the scanning zone to a point close to and in advance of the deflector and to remain closed from a small part only of that interval, fifth switch means connected in series with the second switch means and arranged to be closed only when the fourth switch means is closed, and sixth switch means arranged to be open only when the fourth and fifth switch means are closed.

37. Apparatus as claimed in Claim 36, wherein each of the fourth, fifth and sixth switch means comprises a rotatably mounted wheel having an insulating sector and a conducting sector, and a co-operating fixed contact.

38. Apparatus as claimed in Claim 37, wherein the rotatably mounted wheels are fixed on a common shaft which is so coupled to the feeding means that it executes exactly one revolution in the said interval.

39. Apparatus as claimed in any one of Claims 33 to 38, wherein there is provided two or more separating means arranged to separate the individual sheets into three or more lots, the separating means being connected to the output side of the limiter stage and the arrangement being such that the sheets are separated into different lots in accordance with the number, magnitude or position of the faults on the sheets.

40. Apparatus as claimed in Claim 39, wherein the arrangement is such that the sheets are separated into lots of which one contains sheets that have faults in all zones and the remainder contain sheets that have no faults in certain zones which are such that these latter sheets can be cut to provide faulty part-sheets and faultless part sheets.

41. Apparatus as claimed in any one of Claims 33 to 40, wherein there are provided additional scanning means arranged to scan the material in a second scanning zone situated either to the rear or in advance of the first scanning zone, additional photo-electric means responsive to the intensity of the light reflected and/or transmitted by the material in the second scanning zone, and an additional limiter stage connected to the additional photo-electric means.

42. Apparatus as claimed in Claim 41, wherein the first scanning means is arranged to scan one surface of the material and the additional scanning means is arranged to scan the other surface of the sheet material.

43. Apparatus as claimed in Claim 41 or Claim 42, wherein both the first photo-electric means are arranged to be responsive to the intensity of the light reflected by the material and, in order to prevent inter-sheet gaps from giving rise to fault-indicating signals, there are provided two light sources, one associated with each scanning means arranged to provide a beam of light directed across the path of the sheets and towards the associated photo-electric means, the two light sources being situated in different positions when viewed transversely to the direction of feed of the sheets.

44. Apparatus as claimed in any one of Claims 33 to 43, wherein there is provided

means for counting the number of sheets in each of the said lots.

45. Apparatus as claimed in any one of Claims 33 to 44, wherein there is provided means for introducing marker slip at intervals of a given number of sheets in each of the said lots.

46. Apparatus for checking sheet material for optically detectable irregularities substantially as described with reference to and as shown in Figure 1, or Figure 2, or any one of Figures 4 to 7 of the accompanying drawings.

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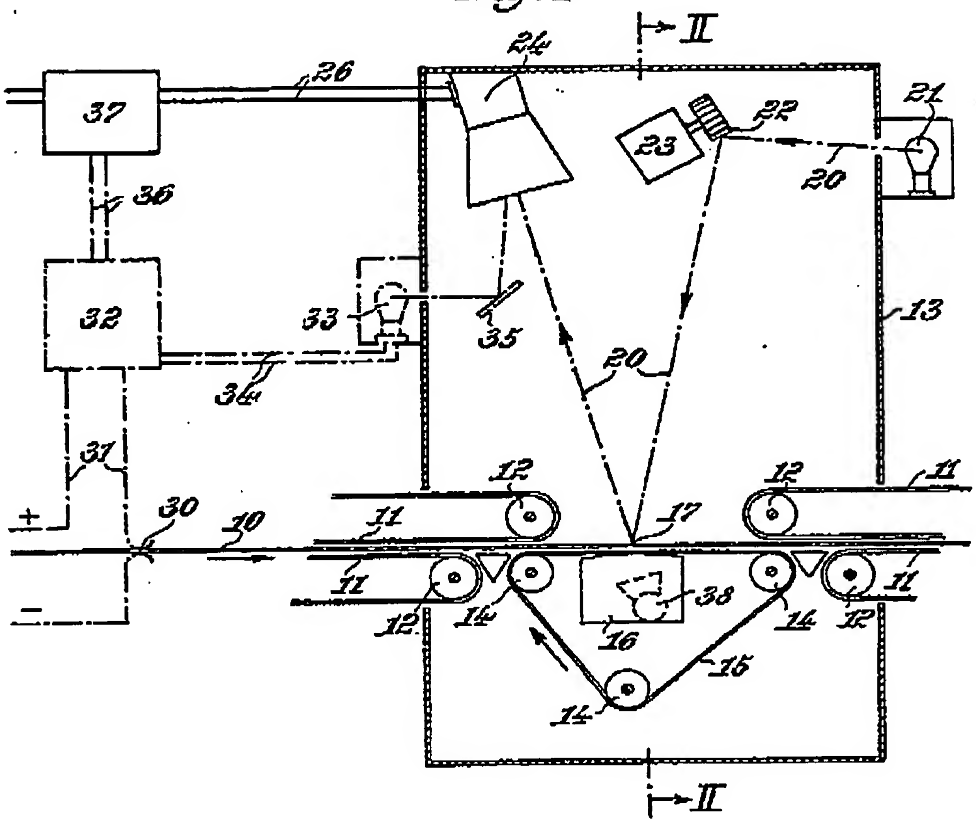
Fig. 1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921,362 COMPLETE SPECIFICATION
5 SHEETS This drawing is a reproduction of the Original on a reduced scale.
SHEETS 1 & 2

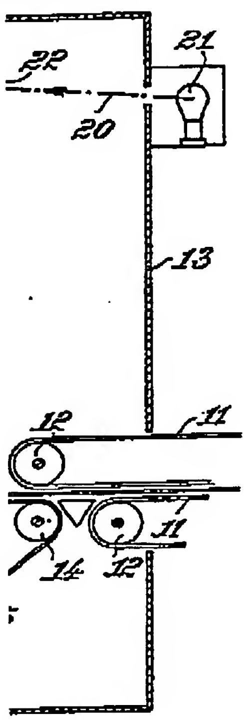
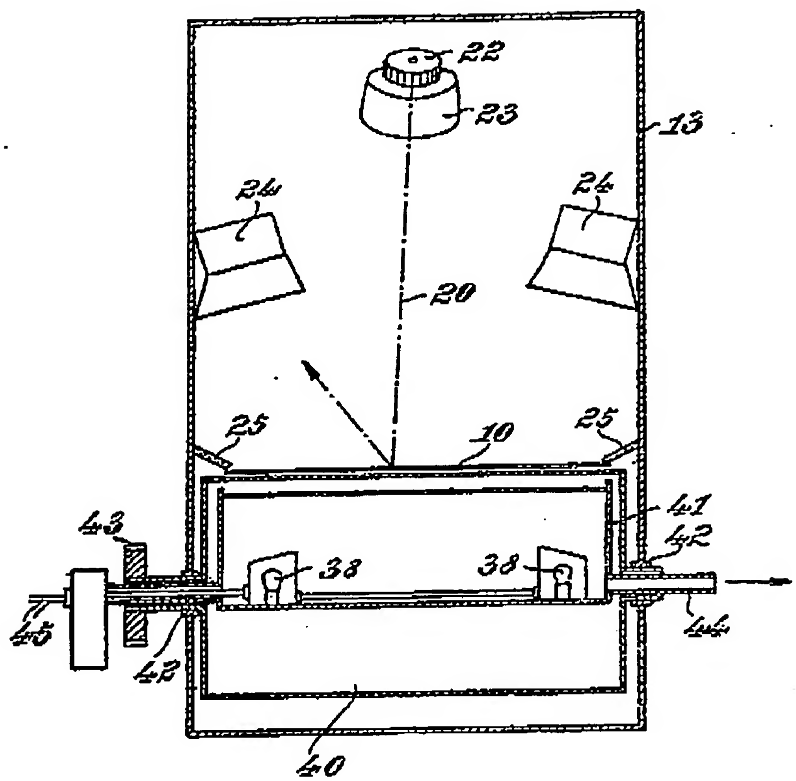


Fig. 2



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SHEETS 1 & 2

Fig. 2

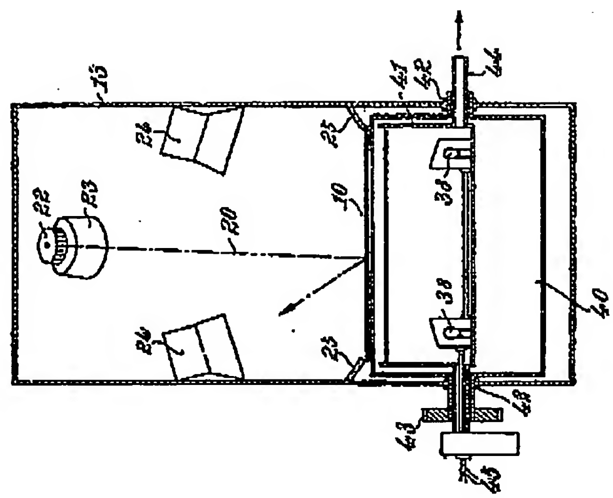


Fig. 1

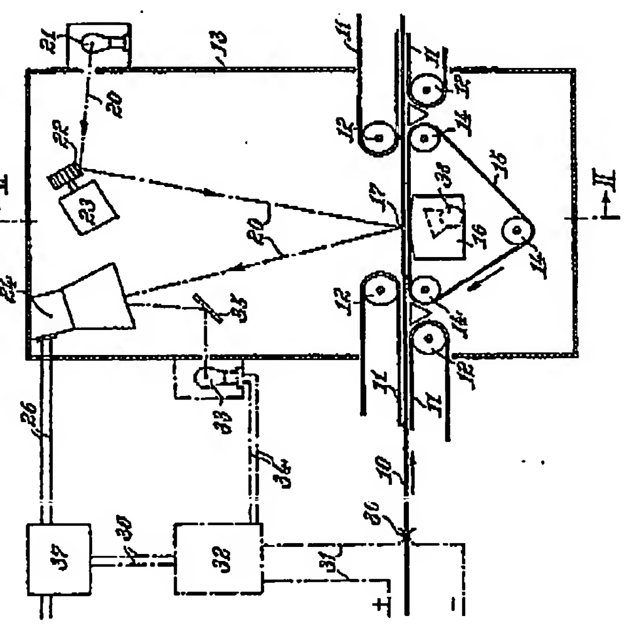
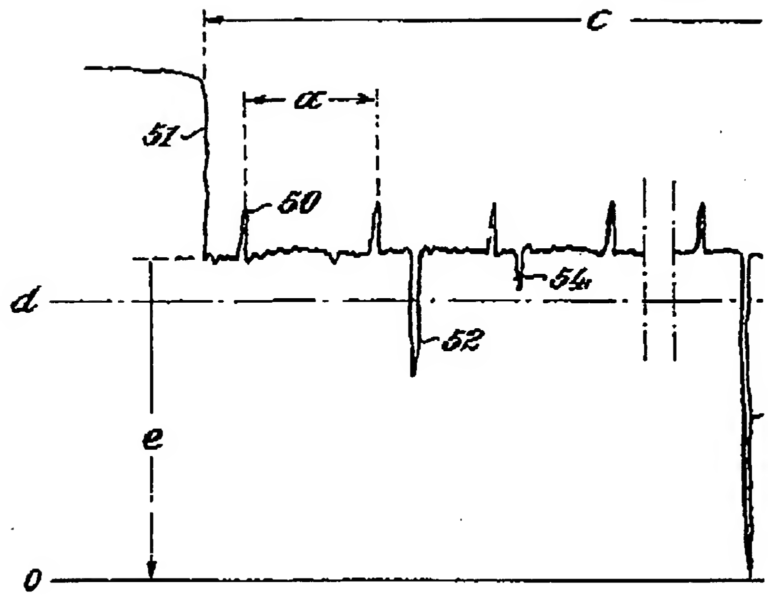


Fig. 3



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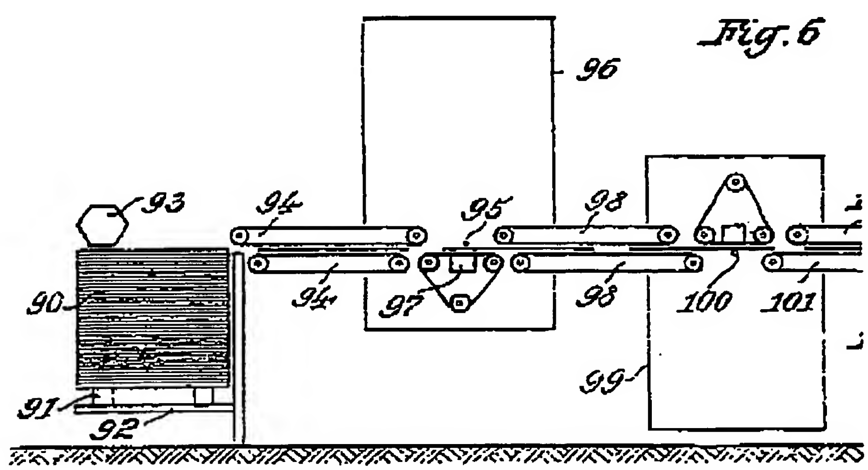

921,362 COMPLETE SPECIFICATION
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SHEET 3

Fig. 3

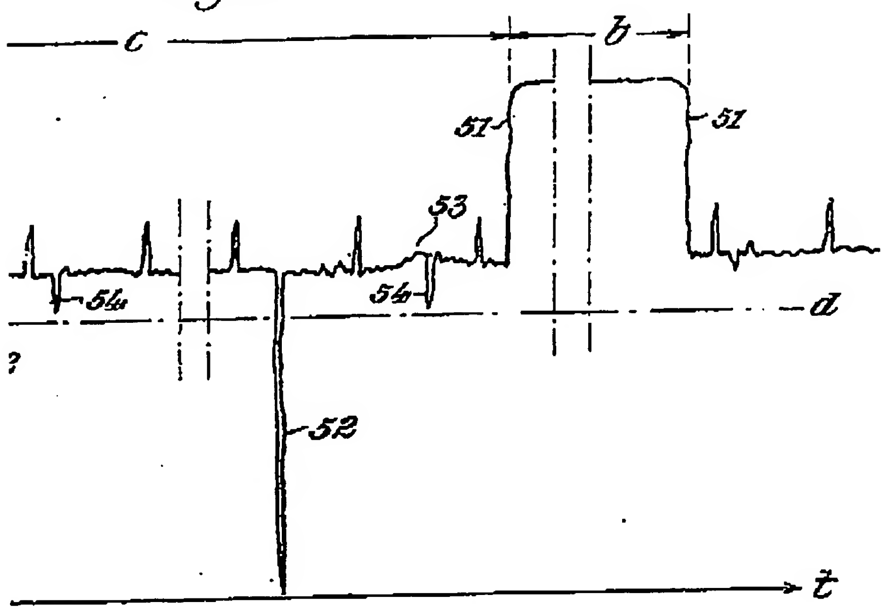
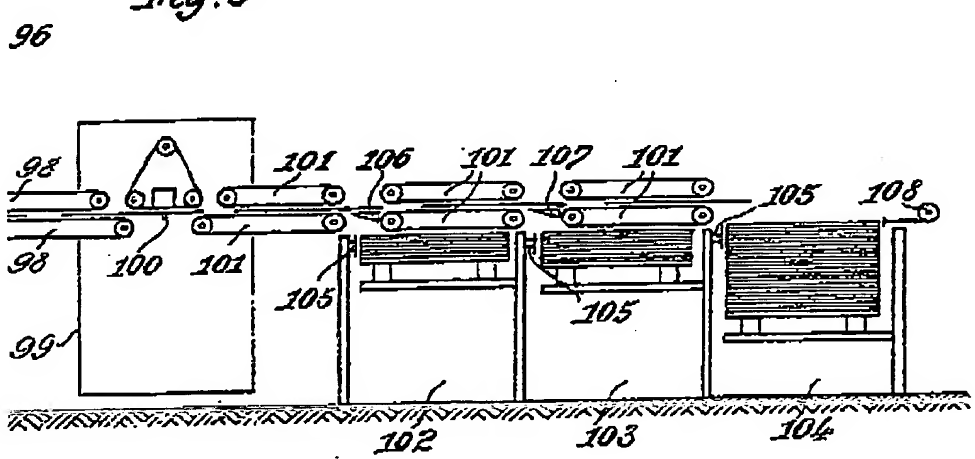


Fig. 6



921,362 5 SHEETS

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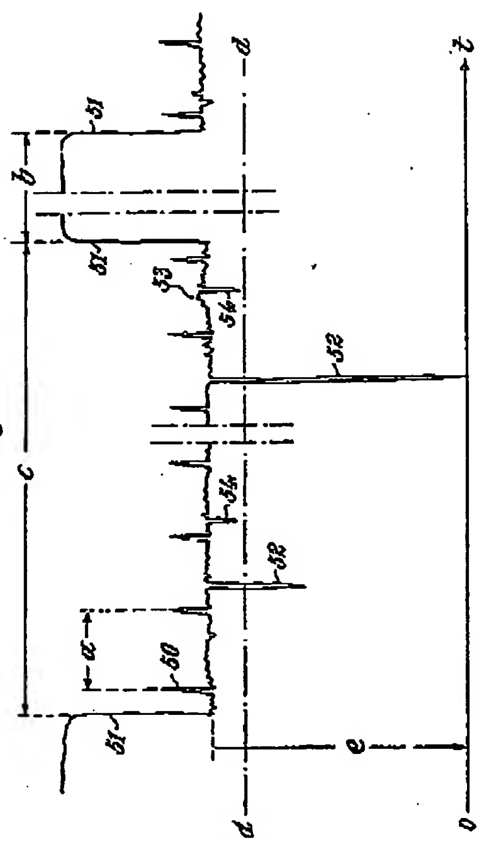
SHEET 3

Fig. 3



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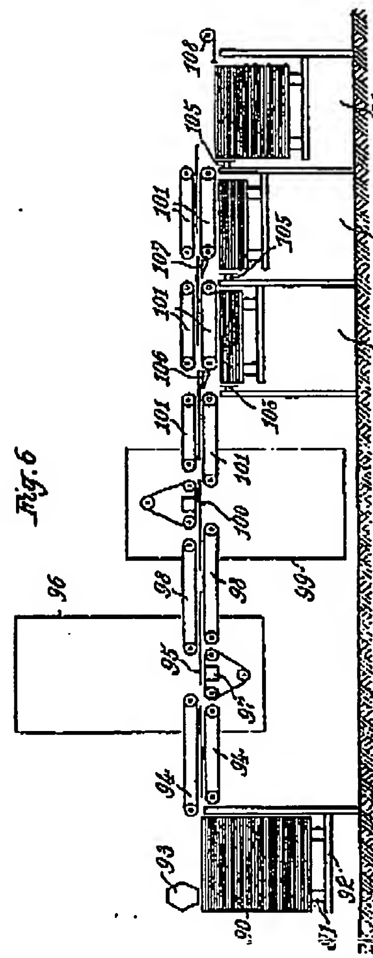

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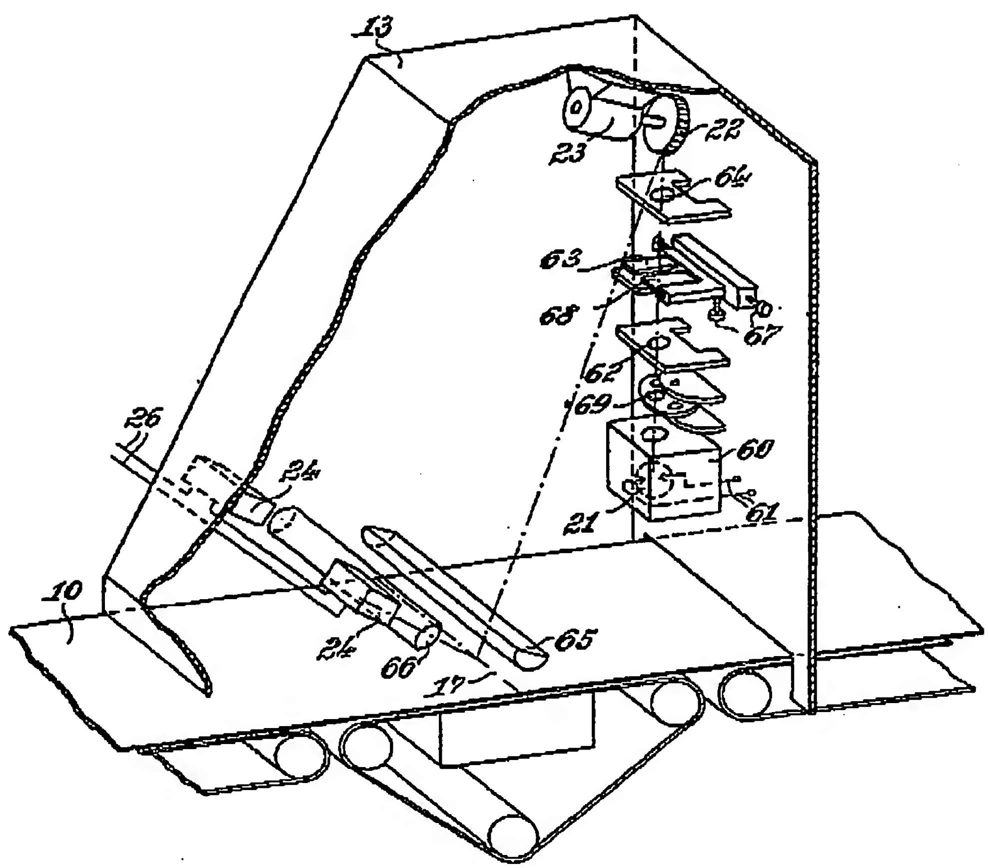

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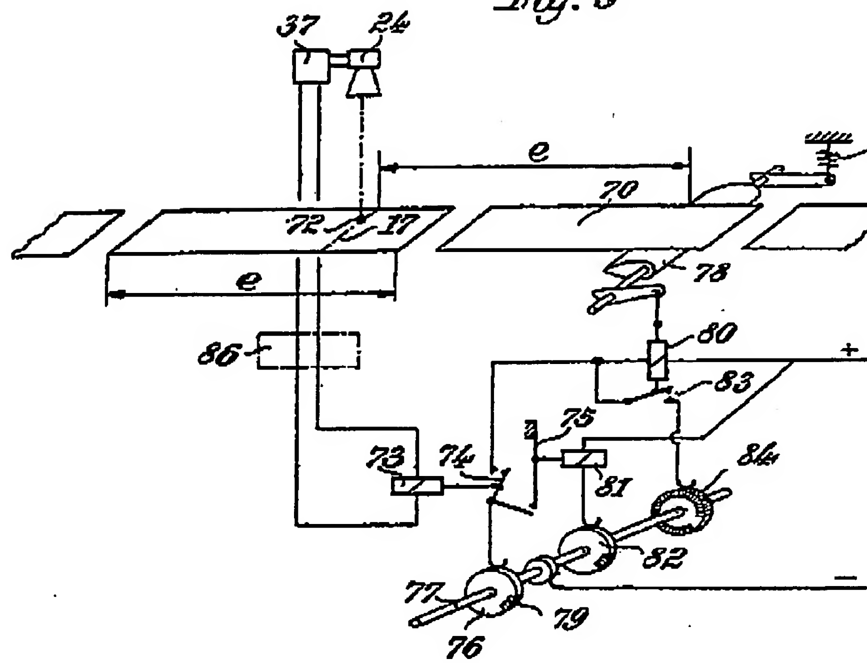
SHEETS 4 & 5

Fig. 5



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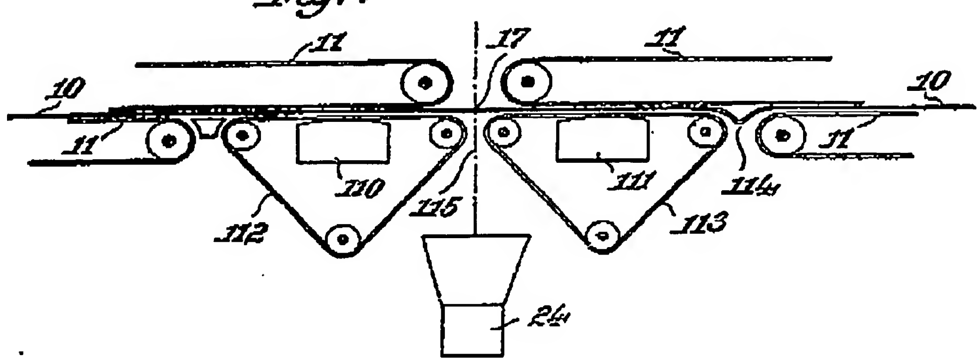

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SHEETS 4 & 5

Fig. 5

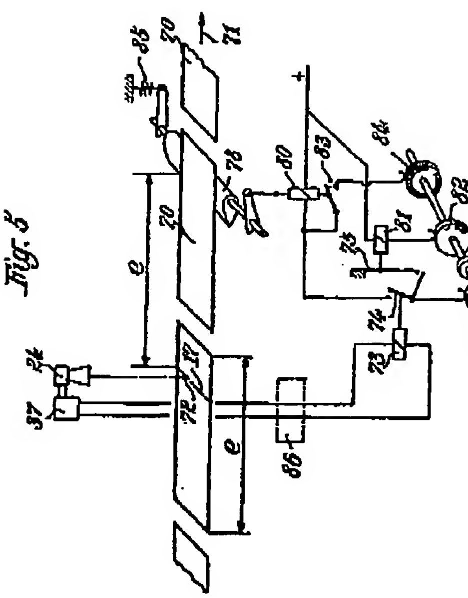

Fig. 7

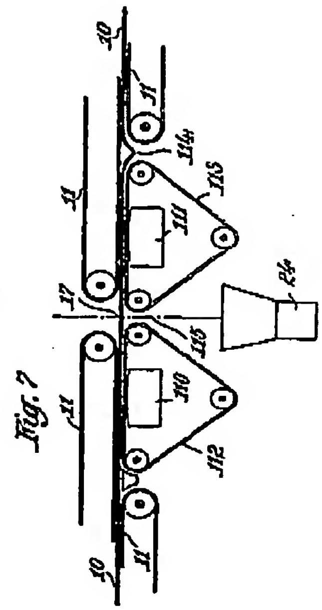

Fig. 4